A Large Open-Ended Coaxial Probe for the Evaluation of the Fiber Content in Steel Fiber Reinforce Concrete Slabs

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Steel fiber reinforced concrete (SFRC) is used for slabs on grade such as pavements, industrial floors, airport runways, since it exhibits excellent isotropic mechanical properties. When mixing the fibers with the fresh concrete, care is taken to obtain a uniform distribution and a random orientation of the fibers. The strength of this concrete primarily depends on the fiber content, hence it is important to be able to detect locations with insufficient fiber content in the hardened slab.

Recently, we developed a non-destructive technique for measuring the steel fiber content, based on the use of microwaves (S. Van Damme *et al*., *IEEE Trans. Geosci. Remote Sensing*, 42, 2511-2521, 2004). The technique combines an accurate open-ended coaxial probe reflectometry method, in order to measure the effective permittivity of the reinforced concrete, with a classical Maxwell-Garnett mixing formula, which establishes the relationship between the effective permittivity and the fiber volume fraction. When using this formula, it is assumed that the fibers are perfectly conducting prolate spheroids with a given aspect ratio and that the permittivity of the concrete without fibers is known. Measurements at 600 MHz with a moderately sized probe (OD = 4 cm) on various SFRC slabs with a thickness of 10 cm were conducted, in which case it is possible to model the slab by a dielectric half space. In this way the rational function approximation (S.S. Stuchly *et al*., *IEEE Trans. Microwave Theory Tech*., 42, 192-198, 1994) can be used to extract the permittivity from the reflection coefficient, but a spatial averaging of several measurements is needed to improve the homogenization.

In this contribution, we have applied a larger probe (OD = 20 cm), such that spatial averaging is no longer needed. Consequently the measurement time is significantly reduced. From a sensitivity analysis, it follows that the optimum frequency range for this probe is 100 MHz - 300 MHz. In this case it is necessary to use a model for the aperture admittance which accounts for the finite layer thickness. We have implemented the exact full wave spectral domain model (P. De Langhe *et al*., *IEEE Trans. Instrum. Meas*., 42, 879-886, 1993). The inversion of this model for the permittivity is done in an iterative manner with a Levenberg-Marquardt optimization. In order to check the classical mixing rule, we have implemented a full-wave Method of Moments technique, with which the field scattered by a collection of PEC wires contained in a canonical shape is simulated and to which the effective permittivity of a homogeneous volume within the same canonical shape is fitted. With this method it is possible to investigate the influence on the effective permittivity of losses in the concrete due to humidity.

We show measurements with the large probe for 10 SFRC slabs with different thicknesses, various concrete compositions and different fiber contents and fiber types. The results with this large probe are quite promising and better than those obtained with the moderate size probe. The error with respect to the expected fiber content lies in a range between 2 % and 10 %.

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